ARMY RESEARCH LABORATORY

Accuracy and Railguns

by Alexander E. Zielinski

ARL-TR-2392

February 2001

Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5066

ARL-TR-2392 **February 2001**

Accuracy and Railguns

Alexander E. Zielinski
Weapons and Materials Research Directorate, ARL

Abstract

Assessment of accuracy is dominated by a detailed experimental investigation of the launch and flight performance of a launcher and round. This assessment is commonly called a jump test. To evaluate the path of the round as it accelerates down the launcher, exits the barrel, and flies downrange to the target, single-shot firings are conducted. In the most recent test, integrated launch packages (ILPs) were launched at an exit velocity of 1,350 m/s. The test provides for the only set of accuracy data available in the world on EM gun-launched projectiles. The impact data show larger variability in the vertical direction than in the horizontal direction. Results from the jump test indicate that effects of the deviation of the launcher centerline (i.e., straightness) contribute significantly to the target impact dispersion. Substantial linear and angular rates at the muzzle are evident in the vertical direction. The contribution attributable to sabot discard is minimal in either plane.

Table of Contents

INTENTIONALLY LEFT BLANK.

List of Figures

INTENTIONALLY LEFT BLANK

1. Introduction

The earliest documented assessment of accuracy for electromagnetic gun-launched projectiles occurred in 1997 [1]. The primary objective of the test program, however, was to verify single-shot performance for the launcher and integrated launch package (ILP). During the course of testing a developmental approach allowed accuracy to be assessed simply due to the multitude of data acquired throughout the duration of the program. The initial results indicated that the largest disturbances were located in the vertical direction (i.e., the rail plane). The in-bore balloting loads created by the deviation of the bore centerline (i.e., straightness) contributed significantly to the round to round dispersion. Unfortunately, testing with this launcher was halted while attempting to demonstrate maximum performance.

In the most recent and most comprehensive jump test, a capacitor bank was used to provide energy to the cannon caliber electromagnetic launcher [2]. The initial charge voltage was 7.2 kV and the muzzle switch, used to ensure zero current at projectile exit, was closed at 2.14 ms [3]. The average peak current for the jump test was 615 kA, ±2 kA. The average launch velocity determined from the multistation flash x-ray images was 1,351 m/s, ±10 m/s. Other electrical data acquired during the shot include the breech, launcher, and muzzle voltages. The voltage data and previous analysis indicate that the rear armature contact transitioned. While transition certainly plays an important role in ILP performance, the entire accuracy evaluation was conducted with a transitioned rear contact.

For evaluating launch dynamics, an aim point and intended line of flight (LoF) is essential; it was established using a boresight. The boresight is inserted in the muzzle end of the launcher and the crosshair in the eyepiece is marked on the downrange target. However, since the boresight is referenced to the bore surface, some misalignment and variability can exist because of the deviations of the bore centerline and surfaces. It was found that the standard deviation for the horizontal direction is 0.36 mil and 0.42 mil in the vertical direction. (One mil corresponds to 1 yd of deflection per 1,000 yd of range.) To reference the launcher LoF to the x-rays, a steel cable was attached at the breech, pulled through the launcher, and suspended over a pulley

5-m downrange. The pulley was aligned with the boresight crosshair. The cable, for indicating LoF, and beads, for referencing the subprojectile center of gravity (cg) location, were superimposed upon each x-ray. The LoF was corrected for misalignment with the boresight reading in the x-ray data reduction software.

Yaw cards (cardboard targets) were consistently used to assess the free-flight aerodynamics of the projectile. Seven yaw cards were placed at measured intervals along the first 40 m of trajectory. New yaw cards were put up before each shot, and the yaw card located at 40 m was indicated with the boresight. The length of the subprojectile impact and the angular orientation relative to a vertical reference line were recorded. The pitch, yaw, and angle of attack (AoA) could then be determined from geometry. The maximum flight range was 222 m.

1.1 Free-Flight Data and Analysis. The free-flight angular motion of the subprojectile was measured using the yaw cards placed along the flight path. The measured angular motion was then fitted to a theoretical model of the yawing motion, which is based on an analytical solution of the yawing motion of a rolling symmetric missile [1, 4]. From the theoretical model, it is possible to extract information about the aerodynamic performance of the subprojectile and quantify the disturbances to the subprojectile during the launch and sabot discard. This establishes the initial conditions for the free-flight angular motion. This information is then used to evaluate aspects of the transitional ballistics which effect the accuracy and dispersion of the subprojectile.

1.2 Jump. In this section, the series of six disturbances from shot start to target impact (TI) are discussed. Jump is a vector, the sum of whose horizontal and vertical components is equal to the linear deviation from the line of fire produced by forces acting on the ILP. These displacements are typically expressed in mils. The first component is the pointing angle (PA) of the muzzle at projectile exit. At the same time, the muzzle experiences a crossing velocity (CV) that is imposed upon the projectile. The third component is the angular deviation of the projectile cg motion (CG) relative to the instantaneous bore centerline at projectile exit. The next component is the net deviation attributable to sabot discard disturbances (SD). The fifth

jump component is the aerodynamic jump (AJ). The final jump component is the displacement attributable to gravity (g) (GD). Each jump component has a variability associated with it. If the individual jump components are independent of each other (i.e., no cross-correlation) and the data are normally distributed (in a statistical sense), the square root of the sum of the individual jump dispersions squared should equal the target impact dispersion (TID). Differences are attributed to measurement errors and cross-correlation. A jump diagram is shown in Figure 1. For the accuracy assessment discussed here, the terms attributable to muzzle motion (PA and CV) are zero due to the relatively stiff launcher mounting. A thorough discussion of projectile jump and its measurement can be found in the literature [5].

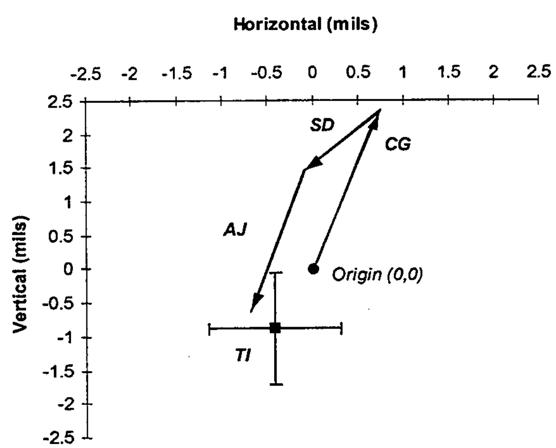

Figure 1. Jump Diagram.

1.3 Linear Rates. Each of the jump components were deduced using a variety of existing transitional ballistic measurement techniques. The CG vector is determined from the location of the subprojectile's cg relative to the fiducial in the multistation orthogonal x-rays. A straight line is fit to the cg locations as a function of range for each plane and the slope of the line is the CG vector. The first three x-ray stations are used to determine the CG vector. The last three x-ray stations are used to determine the final deflection of the subprojectile's trajectory prior to entering free flight. This deflection is determined from the slope of a straight line fit to the cg displacements from the final three x-ray stations. The SD jump occurs after the CG jump and prior to the subprojectile entering free flight. Hence, the SD vector is determined from the

difference between the deflection measured from the last three x-rays and the deflection attributable to the CG vector. An example of the x-ray data for shot 12, with the downrange distances indicated, is shown in Figure 2.

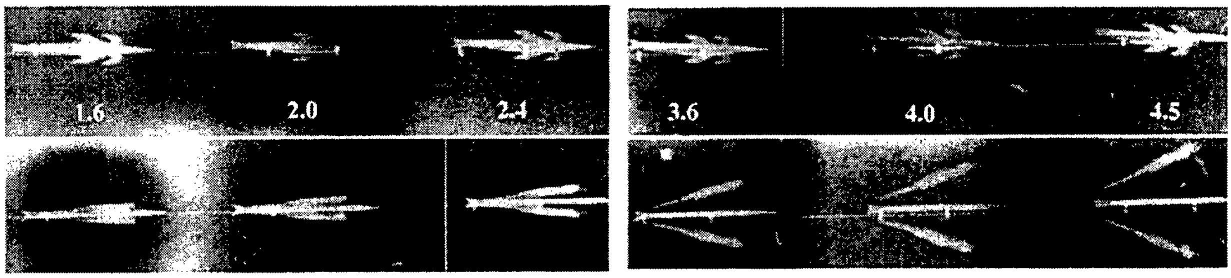

Figure 2. Orthogonal X-ray Images From Shot 12.

Once the subprojectile enters freeflight, it is subjected to aerodynamic forces which may further deflect the flight trajectory of the subprojectile. The deflection due to the aerodynamic forces can be decomposed into mean and fluctuating components. The mean component is referred to as aerodynamic jump and it is produced by the angular rates as the round enters free flight. These rates cause a linear deviation of the mean trajectory from the velocity vector the projectile has entering freeflight. The yaw card data is used to measure the free-flight angular rates. A reasonable approximation for AJ in mils [1] is given as

$$AJ = -1000\frac{I_t C_{L_\alpha}}{m d C_{m_\alpha}}\delta' . \tag{1}$$

The subprojectile moment of inertia (I_t), diameter (d), mass (m), and $C_{m\alpha}$ were measured, whereas $C_{L\alpha}$ was obtained from CFD computations. The angular rate (in rad/m), δ', was determined for each plane, 3.1-m downrange (i.e., free flight) from the fits to the yaw card data.

In addition to the mean deflection of the trajectory, the projectile's swerving motion also has a fluctuating component, s, produced by the aerodynamic forces associated with the yawing motion of the round. These deflections are typically small and are usually not considered in a

jump test where the yaw card targets are many yaw cycles from the muzzle of the gun. Since the impact data used to evaluate the jump components in the present evaluation are taken after approximately one cycle of yawing motion, the fluctuating part of the swerving motion is included. This term represents an additional displacement for each plane along the trajectory. The fluctuating part of the swerving motion can be determined by integrating the equations of motion using the predicted lift coefficient, $C_{L\alpha}$, and the measured yawing motion. The resulting swerving motion is dampened periodically and is accounted for in the jump diagram by correcting the impact location. Fortuitously, s is close to a minimum at the 40-m yaw card which then minimizes the impact on the jump diagram.

Finally, GD, which only appears as a vertical displacement, has been computed in mils from the launch velocity (V) and range (Z) as

$$GD = 1000\frac{gZ}{2V^2}. \qquad (2)$$

The target impact shown in Figure 1 has been corrected for both the fluctuating part of the swerving motion and the vertical displacement due to gravity.

Once the jump vector diagram is assembled for each shot, each vector is referenced from the origin. The variability of the vectors for each component is then computed as the dispersion for the jump component. It is important to note that the summation of the jump vectors without cross-correlations should end at the impact location (i.e., closed). However, sources of measurement error should be accounted for in the analysis. (For example, the impact location is known relative to the bore centerline to within the variability of the boresight.) It is unreasonable to hold the impact location as an error-free datum. An error analysis was conducted on the measured data; the result indicates that for all shots, an average of 4 mm is needed in the horizontal direction and 15 mm in the vertical direction for the trajectory to be within the impact location determined by the boresight. Therefore, based on the boresight variability and x-ray measurement accuracy, the jump diagrams are considered "closed" for each

shot, and no additional vectors are added to the existing components to close with the measured target impact location.

1.4 Angular Rates. The angular rates determined by the first three x-rays are indicative of the in-bore balloting forces acting on the ILP cg. The angular rates associated with free flight are also a result of the armature discard event and represent the final angular motion of the round. The free-flight angular rates are larger in the present jump test than the rates measured in previous tests [1]. The average magnitude of the free-flight angular rate is 1.72°/m in the rail direction and 0.63°/m in the insulator direction. On average, the rates representative of in-bore balloting contribute 65% toward the free-flight rates. Thus, the dominant factor driving AJ is due to in-bore balloting. Similar conclusions were reached in a prior experimental effort [1].

1.5 Dispersion. In Figure 3, the dispersions for the CG, SD, and AJ jump components are plotted for the insulator (horizontal) and rail (vertical) directions. The component dispersions are larger in the rail direction than in the insulator direction. This trend was also observed in previous work [1]. However, the dominant contribution in the rail direction is from the aerodynamic jump, while in the insulator direction it is attributable to in-bore balloting. As alluded to previously, the rates generated from the launcher contribute significantly to the dispersion.

The horizontal and vertical TIDs, based on a linear summation of the jump vectors and no cross-correlation, are 0.62 and 2.07 mils and are quite reasonable compared to the TID measured at the 40-m yaw card target (0.64 and 2.73 mils). This agreement is encouraging since the calculations for the jump vectors do not rely on the target impact location data.

The impact data used to determine the TID was obtained 40-m downrange. The impact data are corrected for the misalignment in the LoF due to boresight errors. Shown in Figure 4 is the TID as a function of launch velocity. Data from previous work on a similar ILP [1], as well as that from a similar-caliber, conventionally-launched munition are also included. The dashed

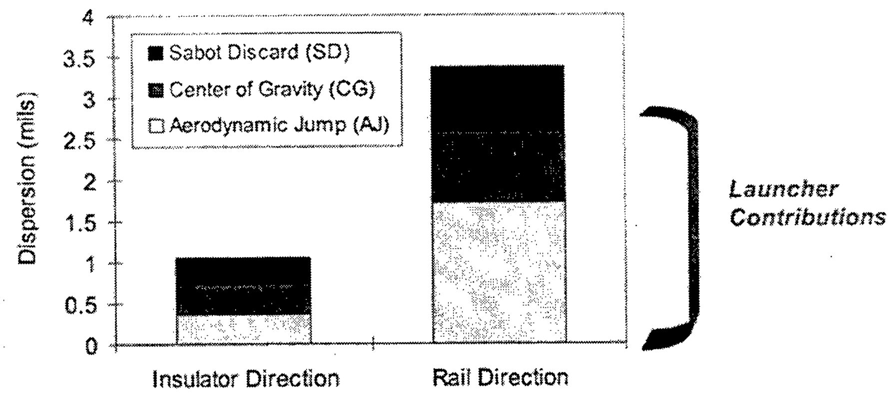

Figure 3. Jump Component Dispersions.

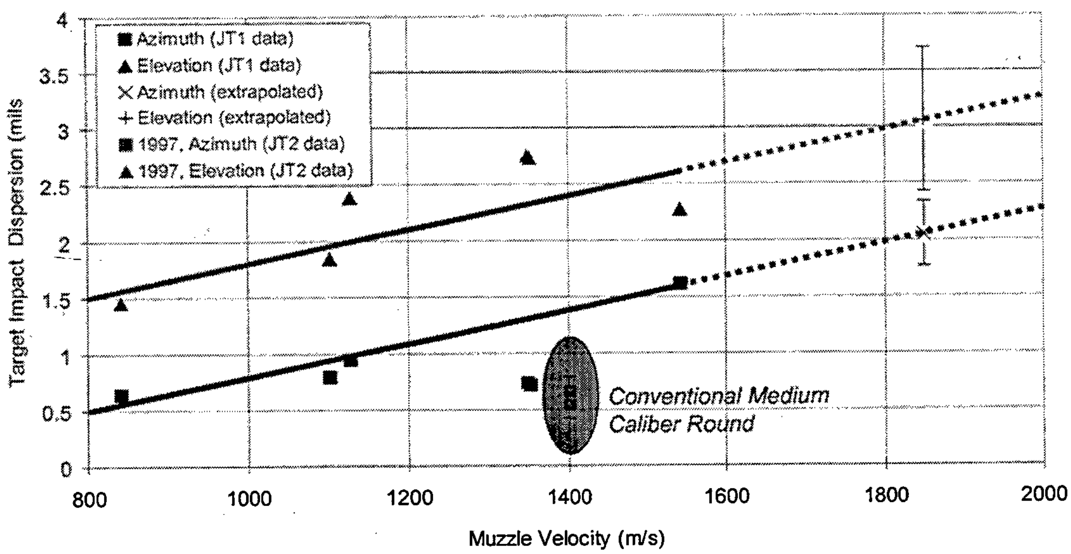

Figure 4. Target Impact Dispersion as a Function of Launch Velocity.

lines are extrapolations of the measured data beyond 1,500 m/s. The TID appears to increase linearly with velocity at a rate of 1.4 mils/km/s. Despite the seemingly linear relationship, further commentary is not warranted since the prior data used an identical launcher with a different centerline.

The correlation of launcher straightness with accuracy and dispersion is not new [6, 7]. The angular rates and variability of the CG jump vector suggest that railgun straightness may be

correlated with accuracy and dispersion. The deviation from the bore centerline is measured as a function of launcher length for the recent assessment and is shown in Figure 5. The vertical component of the CG vector is in agreement with the trend of the centerline in the rail direction at the muzzle. All of the ILPs exit the launcher oriented upwards. However, the same correlation is not evident in the insulator direction. Nonetheless, producing a smoother centerline will certainly contribute to smaller angular and linear rates.

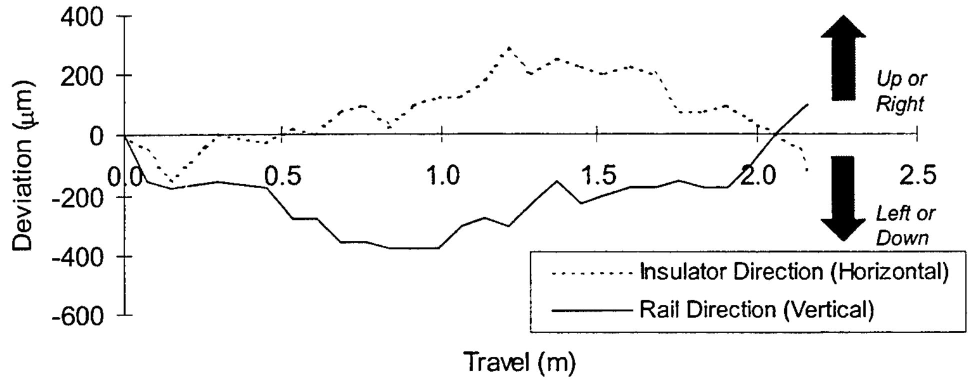

Figure 5. Measurement of the Deviation From the Bore Centerline.

2. Technical Issues

The linear and angular rates produced by the launcher appear to be the major contributor to the TID. The dominant linear rate for both planes was produced by the launcher (CG). The linear rates were effectively managed using a less stiff front armature contact compared to that measured in previous results [1].

The angular rates produced by the launcher contribute significantly toward the free-flight rates. These rates manifest themselves as a linear displacement in aerodynamic jump (AJ). These rates are managed in the subprojectile by the pitching moment coefficient. The goal of further enhancing accuracy is then to balance the contribution of the linear and angular rates through armature and subprojectile design changes so that the combined contribution toward TID is minimized. While this trade-off can be accomplished analytically, obtaining a balance

depends on the rates generated by the launcher; therefore, it can best be quantified only through experiments.

The deviation from the bore centerline (i.e., straightness) has been measured on electromagnetic railguns [8–10]. However, relatively little has been done to collectively assess, quantify, and corroborate the causal relationships. Moreover, even less has been done to address the unique details of railgun centerlines both in terms of manufacturability and accuracy requirements.

3. Conclusions

Accuracy as related to railguns was assessed in a limited number of tests. The most significant contributor to dispersion was found to be correlated with in-bore dynamics associated with the deviation from the bore centerline. It is recommended that this characteristic of the launcher be addressed with respect to manufacturability, as its origination is unclear. Also, the possibility of alternate and/or higher accuracy measurement techniques should be explored.

Other contributors to accuracy not previously addressed include a launcher mount in which the muzzle pointing angle (MP) and crossing velocity (CV) are not zero. The relative effect of armature contact transition and gouging can be readily assessed in separate experiments. Finally, multishot dynamics should be addressed along with consequences for extending bore life.

INTENTIONALLY LEFT BLANK.

4. References

1. Zielinski, A. E., P. Weinacht, D. W. Webb, and K. P. Soencksen. "An Investigation of the Ballistic Performance for an Electromagnetic Gun-Launched Projectile." ARL-TR-1361, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, June 1997.

2. Zielinski, A. E., and M. Werst. "Cannon-Caliber Electromagnetic Launcher." *IEEE Transactions on Magnetics*, vol. 33, no. 1, January 1997.

3. Zielinski, A., and P. Weinacht. "Improved Integrated Launch Package Ballistic Performance." *IEEE Transactions on Magnetics*, January 1999.

4. Murphy, C. H. "Free-Flight Motion of Symmetric Missiles." BRL-TR-1216, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, July 1963.

5. Bornstein, J., I. Celmins, P. Plostins, and E. M. Schmidt. "Techniques for the Measurement of Tank Cannon Jump." BRL-MR-3715, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, December 1988.

6. Garner, J., M. Bundy, D. Webb, and B. Patton. "Variation in Muzzle Pointing Angle and Shot- Impact of a M242 Chain Gun." ARL-TR-785, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, July 1995.

7. Bundy, M., and B. Patton. "Variation in Shot Impacts Due to a Controlled Bending of a Gun Tub. " ARL-TR-1190, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, September 1996.

8. Burton, L. "A Comparison of In-Bore Projectile Motion From an Electromagnetic Railgun vs. That of a Conventional Cannon Barrel." ARL-TR-295, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, October 1993.

9. Burton, L. "In-Bore Dynamic Response Analysis of a SLEKE I Projectile Fired From the Single Shot Gun (SSG) Railgun." ARL-TR-470, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, July 1994.

10. Burton, L. "A RASCAL In-Bore Dynamic Analysis of the Task B and Task C Electromagnetic Railguns." ARL-TR-726, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, April 1995.

INTENTIONALLY LEFT BLANK.

NO. OF COPIES	ORGANIZATION
2	DEFENSE TECHNICAL INFORMATION CENTER DTIC DDA 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1	HQDA DAMO FDT 400 ARMY PENTAGON WASHINGTON DC 20310-0460
1	OSD OUSD(A&T)/ODDDR&E(R) R J TREW THE PENTAGON WASHINGTON DC 20301-7100
1	DPTY CG FOR RDA US ARMY MATERIEL CMD AMCRDA 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	INST FOR ADVNCD TCHNLGY THE UNIV OF TEXAS AT AUSTIN PO BOX 202797 AUSTIN TX 78720-2797
1	DARPA B KASPAR 3701 N FAIRFAX DR ARLINGTON VA 22203-1714
1	US MILITARY ACADEMY MATH SCI CTR OF EXCELLENCE MADN MATH MAJ HUBER THAYER HALL WEST POINT NY 10996-1786
1	DIRECTOR US ARMY RESEARCH LAB AMSRL D D R SMITH 2800 POWDER MILL RD ADELPHI MD 20783-1197

NO. OF COPIES	ORGANIZATION
1	DIRECTOR US ARMY RESEARCH LAB AMSRL DD 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	DIRECTOR US ARMY RESEARCH LAB AMSRL CI AI R (RECORDS MGMT) 2800 POWDER MILL RD ADELPHI MD 20783-1145
3	DIRECTOR US ARMY RESEARCH LAB AMSRL CI LL 2800 POWDER MILL RD ADELPHI MD 20783-1145
1	DIRECTOR US ARMY RESEARCH LAB AMSRL CI AP 2800 POWDER MILL RD ADELPHI MD 20783-1197
	ABERDEEN PROVING GROUND
4	DIR USARL AMSRL CI LP (BLDG 305)

NO. OF COPIES	ORGANIZATION
1	DIR FOR THE DIRECTORATE OF FORCE DEVELOPMENT US ARMY ARMOR CENTER COL E BRYLA FT KNOX KY 40121-5000
1	US ARMY MATERIAL COMMAND AMC DCG T 5001 EISENHOWER BLVD ALEXANDRIA VA 22333-0001
1	US ARMY MISSLE COMMAND AMSMI RD DR MCCORKLE REDSTONE ARSENAL AL 35898-5240
2	US ARMY TACOM TARDEC J CHAPIN M TOURNER AMSTA TR D MS 207 WARREN MI 48397-5000
1	US ARMY TACOM ARDEC J BENNETT FSAE GCSS TMA BLDG 354 PICATINNY ARSENAL NJ 07806-5000
3	INST FOR ADVANCED TECH UNIV OF TEXAS AT AUSTIN P SULLIVAN F STEPHANI T WATT 4030 2 WEST BRAKER LANE AUSTIN TX 78759-5329
4	UNIV OF TEXAS AT AUSTIN CENTER FOR ELECT A WALLS J KITZMILLER S PRATAP J PAPPAS PRC MAIL CODE R7000 AUSTIN TX 78712

NO. OF COPIES	ORGANIZATION
2	LOCKHEED MARTIN VOUGHT L FARRIS MS WT 21 K COOK MS WT 21 PO BOX 650003 DALLAS TX 75265-0003
1	INST FOR DEFENSE ANALYSIS I KOHLBERG 1801 N BEAUREGARD ST ALEXANDRIA VA 22311
1	KAMAN ELECTROMAGNETICS CORP P MONGEAU 2 FOX RD HUDSON MA, 01749
1	UNIV AT BUFFALO SUNY AB J SARJEANT PO BOX 601900 BUFFALO NY 14260-1900
2	UDLP B GOODELL R JOHNSON MS M170 4800 EAST RIVER RD MINNEAPOLIS MN 55421-1498
1	UNIV OF TEXAS AT AUSTIN M DRIGA ENS 434 DEPT OF ECE MAIL CODE 60803 AUSTIN TX 78712
1	SAIC G CHRYSSOMALLIS 3800 WEST 80TH ST SUITE 1090 BLOOMINGTON MN 55431
1	SAIC J BATTEH 4901 OLDE TOWNE PARKWAY SUITE 200 MARIETTA GA 30068

NO. OF COPIES	ORGANIZATION
1	SAIC K A JAMISON 1247 B N EGLIN PKWY SHALIMAR FL 32579
2	IAP RESEARCH INC D BAUER J BARBER 2763 CULVER AVE DAYTON OH 45429-3723
3	MAXWELL TECHNOLOGIES P REIDY T WOLFE 9244 BALBOA AVENUE SAN DIEGO CA 92123
1	NORTH CAROLINA STATE UNIV M BOURHAM DEPT OF NUCLEAR ENGR BOX 7909 RALEIGH NC 27695-7909
1	MAXWELL PHYSICS INTERNATIONAL C GILMAN 2700 MERCED STREET PO BOX 5010 SAN LEANDRO CA 94577-0599
1	ATA ASSOCIATES W ISBELL PO BOX 6570 SANTA BARBARA CA 93160-6570

NO. OF COPIES	ORGANIZATION
	ABERDEEN PROVING GROUND
21	DIR USARL AMSRL WM E SCHMIDT A TANNER AMSRL B A HORST AMSRL WM TE J POWELL AMSRL WM B B FORCH AMSRL WM BA D LYON AMSRL WM BC P PLOSTINS J GARNER V OSKAY M BUNDY G COOPER J SAHU P WEINACHT H EDGE B GUIDOS A ZIELINSKI D WEBB K SOENCKSEN S WILKERSON T ERLINE J NEWILL

INTENTIONALLY LEFT BLANK.

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 2001	Final, Jan 00 - June 00

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Accuracy and Railguns	1L1622618.AH80
6. AUTHOR(S) Alexander E. Zielinski	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory ATTN: AMSRL-WM-BC Aberdeen Proving Ground, MD 21005-5069	8. PERFORMING ORGANIZATION REPORT NUMBER ARL-TR-2392
9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)	10.SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT*(Maximum 200 words)*

Assessment of accuracy is dominated by a detailed experimental investigation of the launch and flight performance of a launcher and round. This assessment is commonly called a jump test. To evaluate the path of the round as it accelerates down the launcher, exits the barrel, and flies downrange to the target, single-shot firings are conducted. In the most recent test, integrated launch packages (ILPs) were launched at an exit velocity of 1,350 m/s. The test provides for the only set of accuracy data available in the world on EM gun-launched projectiles. The impact data show larger variability in the vertical direction than in the horizontal direction. Results from the jump test indicate that effects of the deviation of the launcher centerline (i.e., straightness) contribute significantly to the target impact dispersion. Substantial linear and angular rates at the muzzle are evident in the vertical direction. The contribution attributable to sabot discard is minimal in either plane.

14. SUBJECT TERMS	15. NUMBER OF PAGES
railgun, accuracy, jump test, straightness, centerline	18
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

INTENTIONALLY LEFT BLANK.

USER EVALUATION SHEET/CHANGE OF ADDRESS

This Laboratory undertakes a continuing effort to improve the quality of the reports it publishes. Your comments/answers to the items/questions below will aid us in our efforts.

1. ARL Report Number/Author ARL-TR-2392 (Zielinski) Date of Report February 2001

2. Date Report Received ______

3. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which the report will be used.) ______

4. Specifically, how is the report being used? (Information source, design data, procedure, source of ideas, etc.) ______

5. Has the information in this report led to any quantitative savings as far as man-hours or dollars saved, operating costs avoided, or efficiencies achieved, etc? If so, please elaborate. ______

6. General Comments. What do you think should be changed to improve future reports? (Indicate changes to organization, technical content, format, etc.) ______

CURRENT ADDRESS

Organization

Name E-mail Name

Street or P.O. Box No.

City, State, Zip Code

7. If indicating a Change of Address or Address Correction, please provide the Current or Correct address above and the Old or Incorrect address below.

OLD ADDRESS

Organization

Name

Street or P.O. Box No.

City, State, Zip Code

(Remove this sheet, fold as indicated, tape closed, and mail.)

(DO NOT STAPLE)